Supplementary Information

Room-temperature solution processed SnO$_x$ as electron extraction layer for inverted organic solar cells with superior thermal stability

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**Figure S1:** XPS spectrum of the Sn3d peaks of a pristine SnO$_x$ layer. The peaks have been fit using a Gauss-Lorentz profile.
Figure S2. Characteristics of OSCs with a varied thickness of the pristine SnO$_x$ layer. (a) PCE, (b) $V_{oc}$, (c) $J_{sc}$ and (d) FF. Each data point is an average over all cells with the same SnO$_x$ thickness on one substrate.
OSC devices with a SnO$_x$ layer that has either been annealed in air or has been treated with an oxygen plasma show strongly S-shaped $I$-$V$ characteristics. It is known that an injection barrier at the electrode does not cause S-shaped $I$-$V$ characteristics in BHJ solar cells but rather leads to a reduction of $V_{oc}$.[1, 2] This can be seen for the $I$-$V$ curve of a device without electron extraction interlayer (ITO only) which shows a low $V_{oc} = 0.23$ V and a low $FF$ but no pronounced S-shape. Similarly, a low $V_{oc}$ is also found for the device with the plasma treated SnO$_x$ layer. Its high WF of 5.13 eV makes an injection barrier for electrons a likely explanation. In recent reports, severely S-shaped $I$-$V$ characteristics have been unambiguously associated with a strongly limited extraction of charges.[1-3] This hints to a poor electron extraction if annealed or plasma treated SnO$_x$ is used. The dramatically decreased conductivity of SnO$_x$ layers annealed in air ($\sim$3-6×10$^{-6}$ S/cm) compared to the pristine
layers (~1-2×10^{-5} S/cm) also leads to deteriorated device characteristics. Specifically, a high series resistance of 100 Ωcm^2 is found for the devices with air annealed SnO_x compared to 1.8 Ωcm^2 for that based on the pristine SnO_x.

**Table S1.** Characteristics (open circuit voltage (V_{oc}), short-circuit current density (J_{sc}) and filling factor (FF)) of inverted OSCs with TiO_x layer. The cells are either pristine or have been treated in climate cabinet for 60 min. The devices are without encapsulation.

<table>
<thead>
<tr>
<th></th>
<th>PCE [%]</th>
<th>V_{oc} [V]</th>
<th>J_{sc} [mA cm^{-2}]</th>
<th>FF [%]</th>
<th>R_s [Ω cm^2]</th>
</tr>
</thead>
<tbody>
<tr>
<td>TiO_x (pristine cell)</td>
<td>3.0</td>
<td>0.52</td>
<td>10.0</td>
<td>57</td>
<td>2.7</td>
</tr>
<tr>
<td>TiO_x (80°C/30%rh)</td>
<td>2.6</td>
<td>0.53</td>
<td>10.0</td>
<td>50</td>
<td>5.1</td>
</tr>
<tr>
<td>TiO_x (80°C/80%rh)</td>
<td>1.4</td>
<td>0.53</td>
<td>8.5</td>
<td>32</td>
<td>12.8</td>
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</tbody>
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